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# Algorithm mismatch in spatial steganalysis

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# Algorithm mismatch in spatial steganalysis

## Disciplines

Forensic Science and Technology

## Comments

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# *Algorithm Mismatch in Spatial Steganalysis*

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# Overview

- Introduction
- Algorithm Mismatch Approach to Blind Detection
- Algorithm Mismatch Results
- Conclusion

# Steganography and Steganalysis

Cover

+

Payload text


=

Steganography: "*covered writing*" (Greek)

Steganalysis: detecting hidden messages

Stego



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# Algorithm Mismatch in Blind Detection

- Motivation
  - Our ultimate goal is to create a uncomplicated, non-data-intensive framework for blind steganalysis
  - The framework consists of a single binary classifier with single known embedding algorithm that will detect stegos with other unknown embedding algorithms
  - Addresses the real-world scenario where training data and processing time are limited
- *Algorithm Mismatch* is the case where a classifier is trained on one stego embedding algorithm and tested others

# Previous Blind Detection Approaches

- Multi-classifier approach
  - Set of (n choose 2) binary classifiers predicts cover or stego and the embedding algorithm [Pevny and Fridrich 2008]
- Domain adaptation approach
  - Domain adaptation in DCT domain to predict cover or stego [Kong et. al. 2016]
- Other approaches
  - One-class classifier trained on covers [Pevny and Fridrich 2008]
  - Binary classifier trained on covers and collection of stego algorithms predicts cover or stego [Pevny and Fridrich 2008]
  - Clustering predicts guilty actors in pooled steganalysis [Ker and Pevny 2011]

# Algorithm Mismatch in Blind Detection

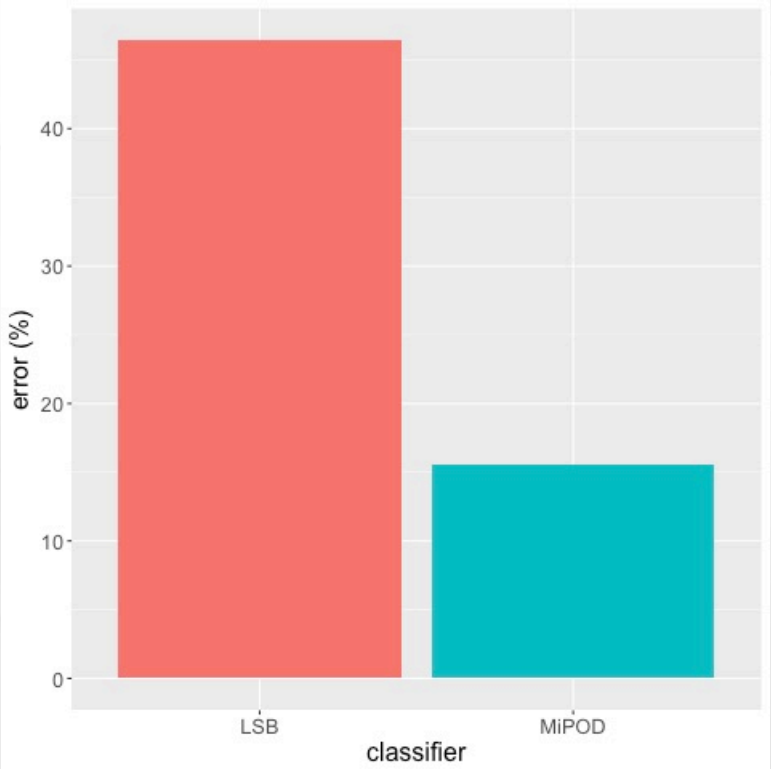
- *Algorithm Mismatch* is the case where a classifier is trained on one stego embedding algorithm and tested other algorithms
- We consider the case where spatial embedding algorithms make changes in the LSB plane only
- We adjust the Ensemble Classifier with Spatial Rich Model features
- 4 embedding algorithms: LSB matching, MiPOD, S-UNIWARD, and WOW
- Uncomplicated, non-data-intensive approach to algorithm mismatch in blind steganalysis

# Datasets Used

- Dataset 1: BOSSbase
  - 10,000 RAW images from 7 digital still cameras. Converted to TIFF (Photoshop). Center-cropped 512x512 images, converted to grayscale and saved as PNG (Matlab)
  - 4 stego algorithms: LSB matching, MiPOD, S-UNIWARD, WOW
- Dataset 2: StegoAppDB – Forensic Image Database
  - 1,927 TIFF auto-exposure images from 6 iPhone devices. Cropped into 5 disjoint 512x512 images, converted to grayscale and saved as PNG (Matlab) for a total of 9,635 covers
  - 4 stego algorithms: LSB matching, MiPOD, S-UNIWARD, WOW

# Motivating Example

Average detection error on BOSSbase MiPOD data




- Test data is BOSSbase covers and MiPOD with 10% embedding rate
- "best-case" classifier is a MiPOD trained classifier
- MiPOD classifier achieves 16% error rate
- LSB trained classifier has error rate close to random guessing



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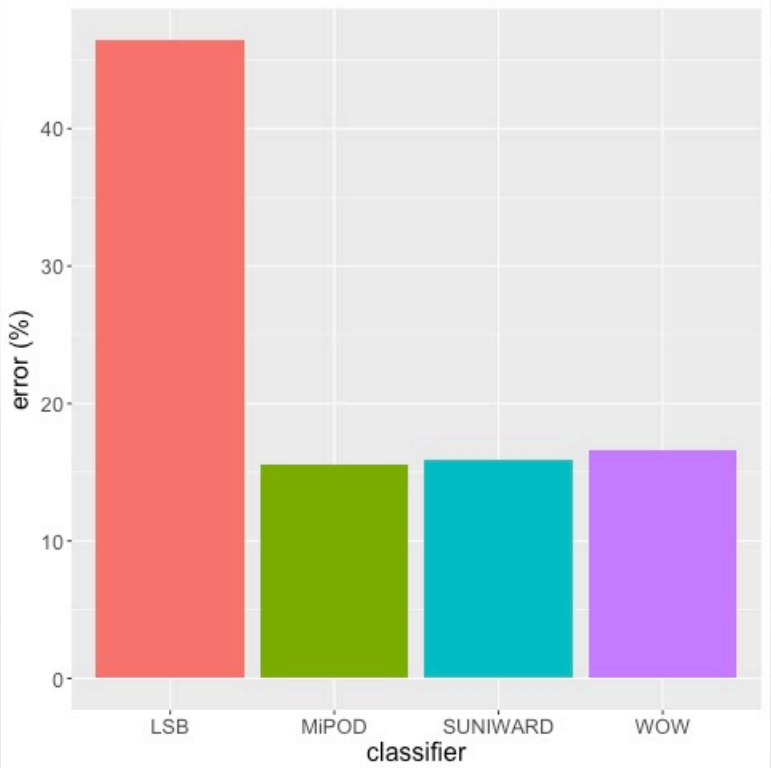
# Motivating Example

Average detection error on BOSSbase MiPOD data



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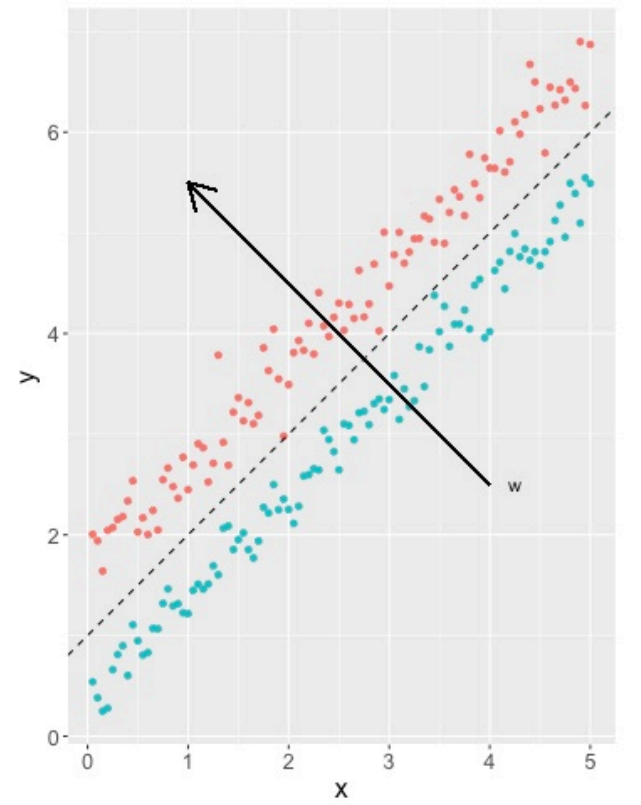
# Fischer Linear Discriminant

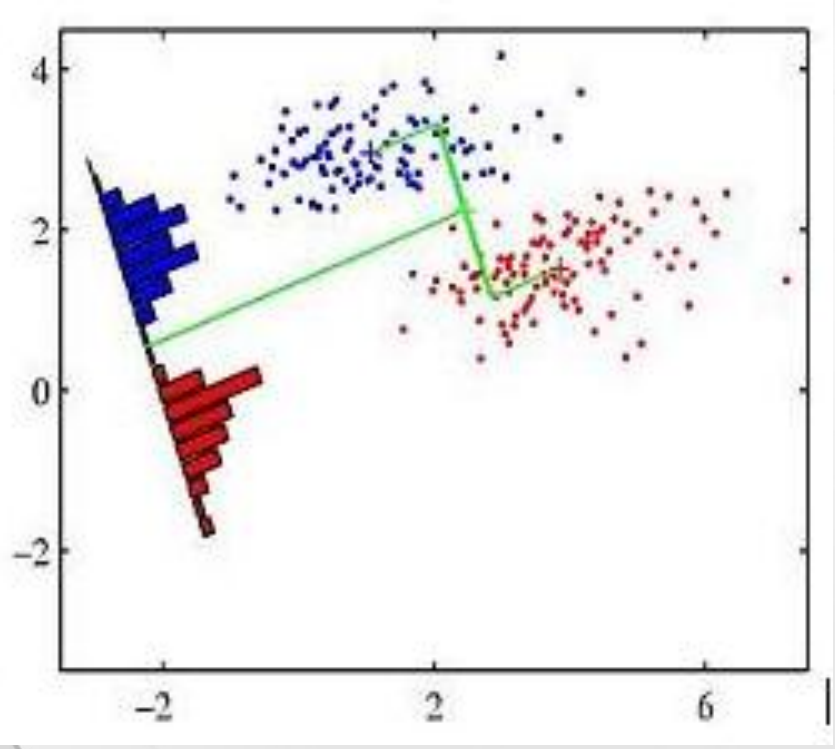



- The Ensemble Classifier consists of a set of base learners
- Each base learner is a Fischer Linear Discriminant
  - An FLD finds the vector $w$ that maximizes the between-class variance and minimizes the within-class variance
  - $w$ is the normal vector for the decision hyperplane $b$, also called the threshold
  - Test image $x$ is projected onto $w$

    $$g(x) = w^T x$$
  - The class is predicted based on which side of $b$ the projection lies

    $$\begin{cases} g(x) > b, & x \text{ is stego} \\ g(x) < b, & x \text{ is cover} \end{cases}$$
  - The *standard* threshold $b$ is chosen to minimize the False Alarm Rate and Missed Detection Rate

# Fischer Linear Discriminant

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  - The *standard* threshold $b$ is chosen to minimize the False Alarm Rate and Missed Detection Rate

# Adjusting the Fisher Linear Discriminant

- When training on LSB data, we adjust the decision threshold

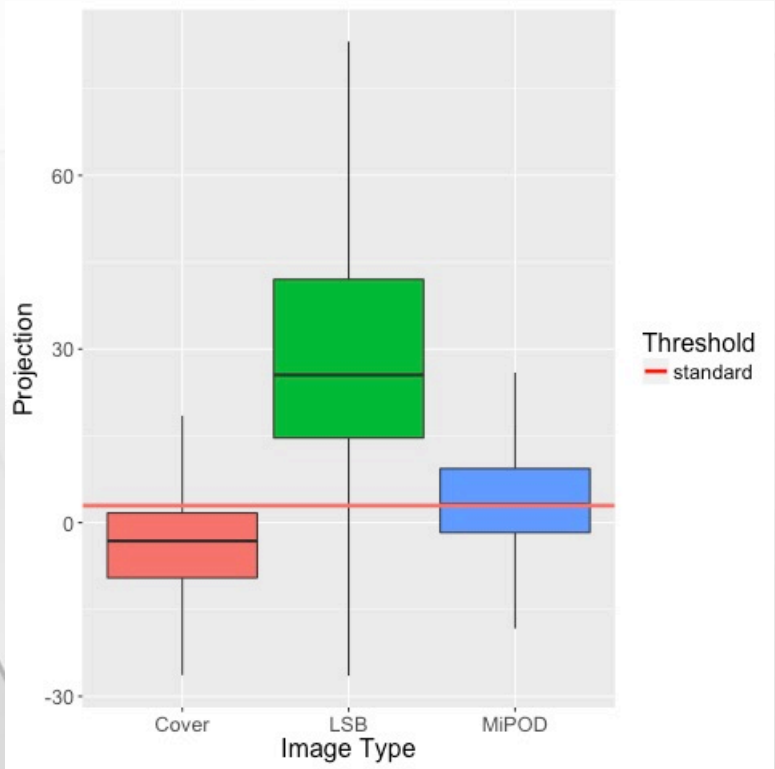
$$b_{adj} = b - \lambda c$$

  - $c$ is the standard deviation of the projections of the training data
  - $\lambda$ is a tuning parameter
  - Experimentally, we found the parameter $\lambda = 0.75$ to give good overall detection results when testing on MiPOD and S-UNIWARD
- Test image $x$ is projected onto $w$. The class is predicted based on which side of $b_{adj}$ the projection lies

$$\begin{cases} g(x) = w^T x > b_{adj} & x \text{ is stego} \\ g(x) = w^T x < b_{adj} & x \text{ is cover} \end{cases}$$

# Why Does Algorithm Mismatch Work?

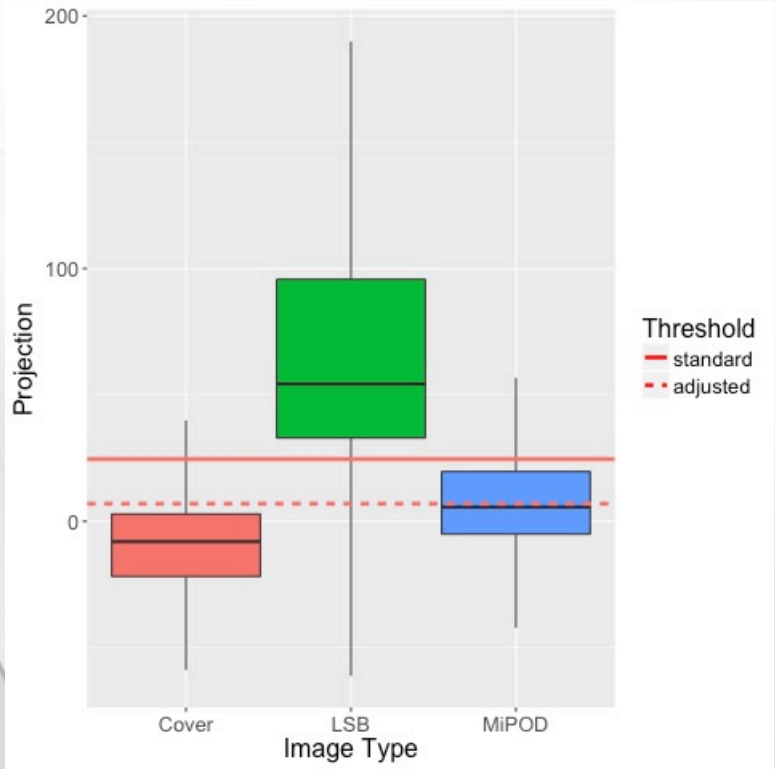
FLD projections of test image features onto normal vector of decision hyperplane




- Best-case classifier - MiPOD trained ensemble classifier with standard threshold
- 10% embedding rate
- 5 repetitions of 10-fold-cross validation
- Each test image projected onto normal vector of decision hyperplane
- Threshold is median across all base learners
- Outliers not shown (~12%)

# Why Does Algorithm Mismatch Work?

FLD projections of test image features onto normal vector of decision hyperplane




- LSB trained ensemble classifier with adjusted threshold
- 10% embedding rate
- 5 repetitions of 10-fold-cross validation
- Each test image features projected onto normal vector of decision hyperplane
- Thresholds are medians across all base learners
- Outliers not shown (~12%)



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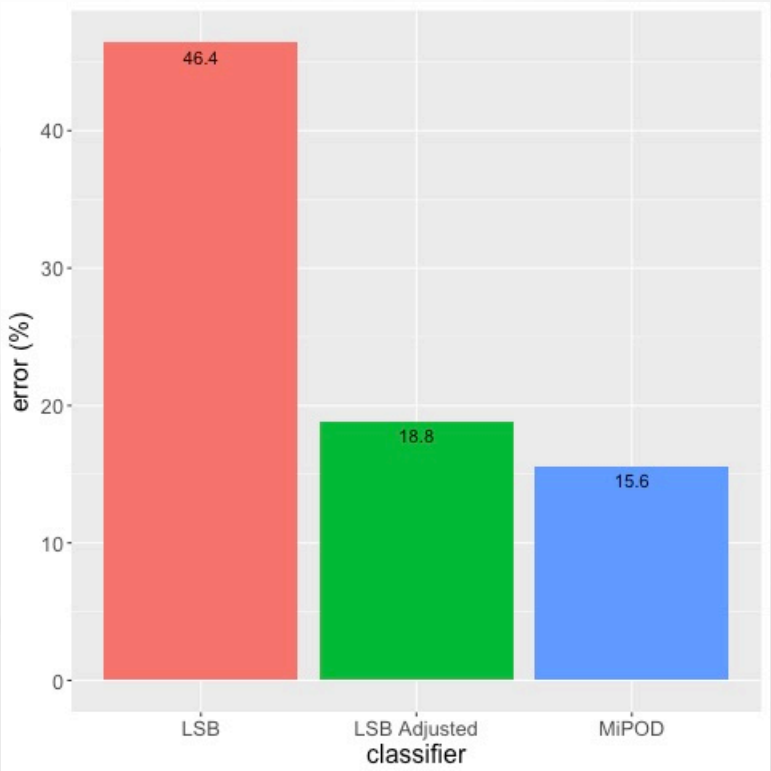
# Terminology

- LSB (MiPOD, S-UNIWARD, WOW) Classifier – an ensemble classifier trained on covers and LSB (MiPOD, S-UNIWARD, WOW) matching data with the standard decision threshold
- LSB Adjusted Classifier – an ensemble classifier trained on covers and LSB matching data with an adjusted decision threshold

# Dataset 1: BOSSbase - 40% Embedding Rate

Average detection error on BOSSbase MiPOD data




- Testing on MiPOD 40% embedding rate
  - LSB Adjusted classifier uses adjusted threshold
  - MiPOD classifier uses standard threshold
  - Training set is 5,000 randomly selected cover-stego pairs and results averaged over 5 repetitions
- LSB adjusted classifier similar results to the “best-case” classifier



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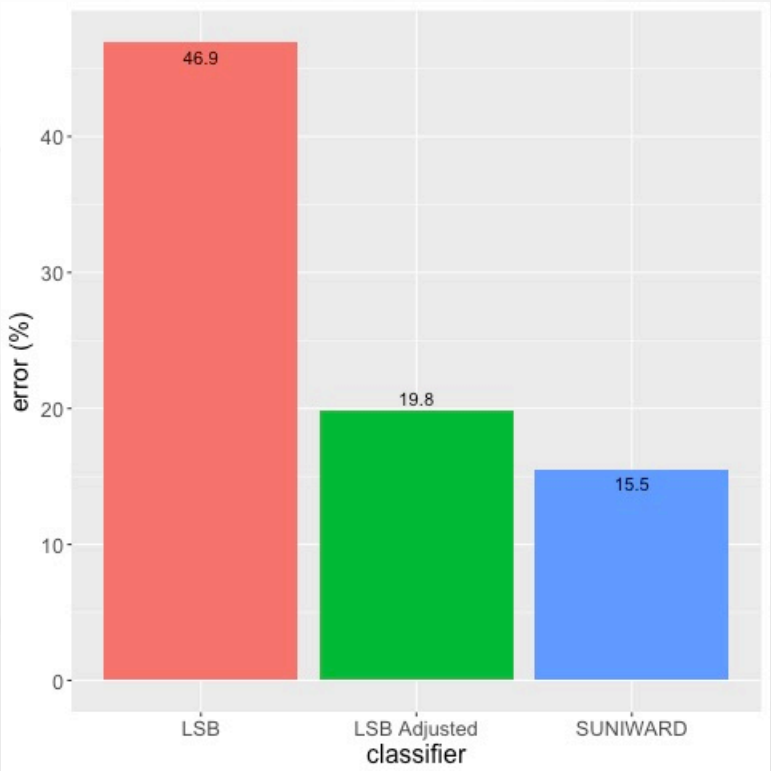
# Dataset 1: BOSSbase - 40% Embedding Rate

Average detection error on BOSSbase S-UNIWARD data




- Testing on S-UNIWARD 40% embedding rate
  - LSB Adjusted classifier uses adjusted threshold
  - Training set is 5,000 randomly selected cover-stego pairs and results averaged over 5 repetitions
- LSB adjusted classifier similar results to the “best-case” classifier



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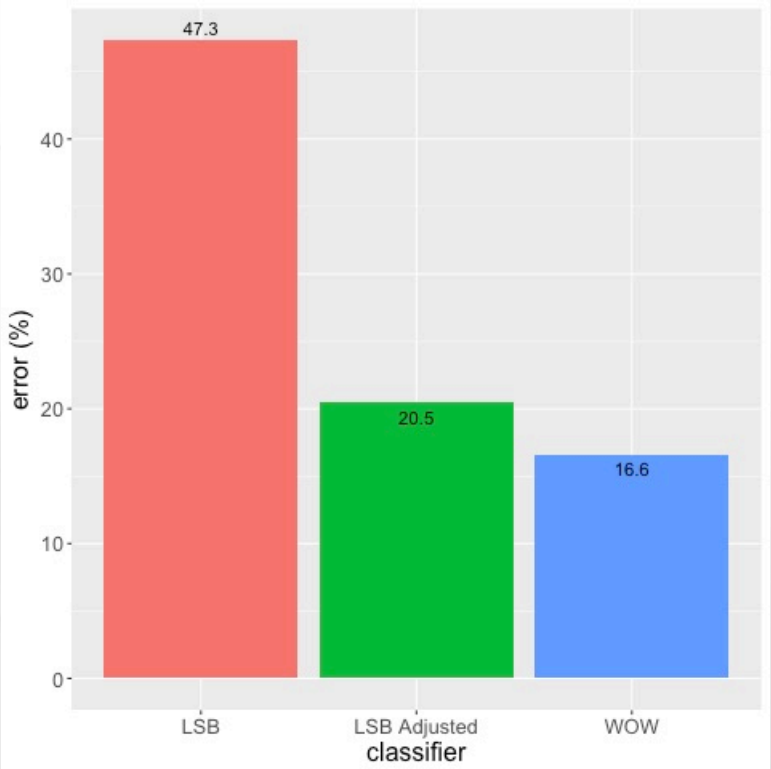
# Dataset 1: BOSSbase - 40% Embedding Rate

Average detection error on BOSSbase WOW data




- Testing on WOW 40% embedding rate
  - LSB Adjusted classifier uses adjusted threshold
  - Training set is 5,000 randomly selected cover-stego pairs and results averaged over 5 repetitions
- LSB adjusted classifier similar results to the “best-case” classifier



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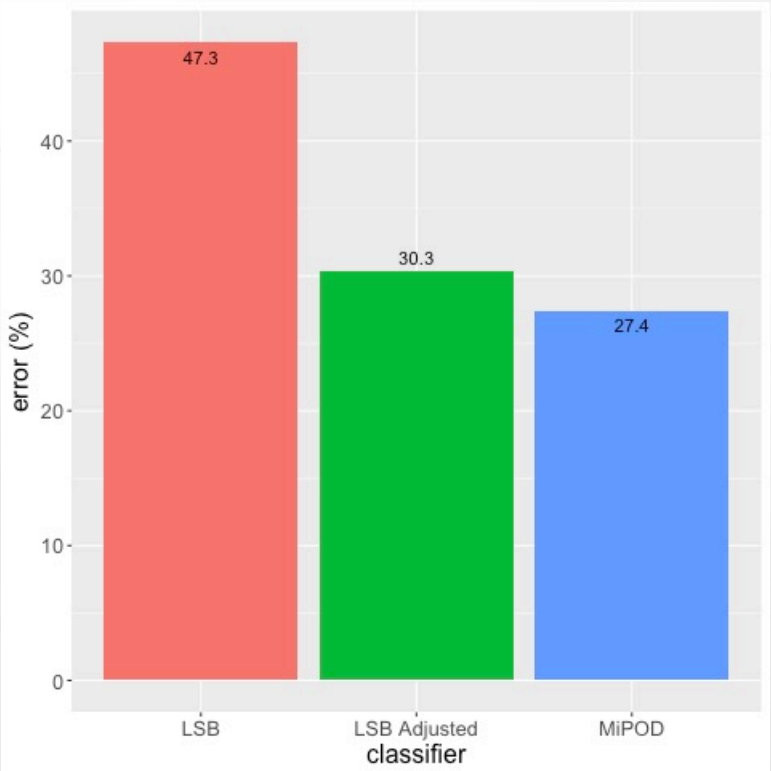
# Dataset 1: BOSSbase - 20% Embedding Rate

Average detection error on BOSSbase MiPOD data




- Testing on MiPOD 20% embedding rate
  - LSB Adjusted classifier uses adjusted threshold
  - MiPOD classifier uses standard threshold
  - Training set is 5,000 randomly selected cover-stego pairs and results averaged over 5 repetitions
- LSB adjusted classifier similar results to the “best-case” classifier



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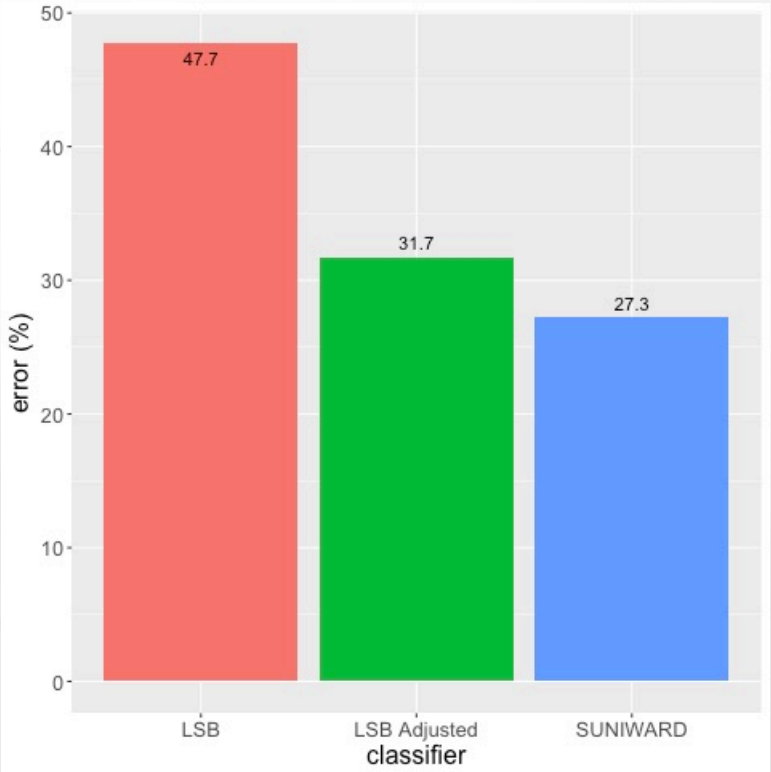
# Dataset 1: BOSSbase - 20% Embedding Rate

Average detection error on BOSSbase S-UNIWARD data




- Testing on S-UNIWARD 20% embedding rate
  - LSB Adjusted classifier uses adjusted threshold
  - S-UNIWARD classifier uses standard threshold
  - Training set is 5,000 randomly selected cover-stego pairs and results averaged over 5 repetitions
- LSB adjusted classifier similar results to the “best-case” classifier



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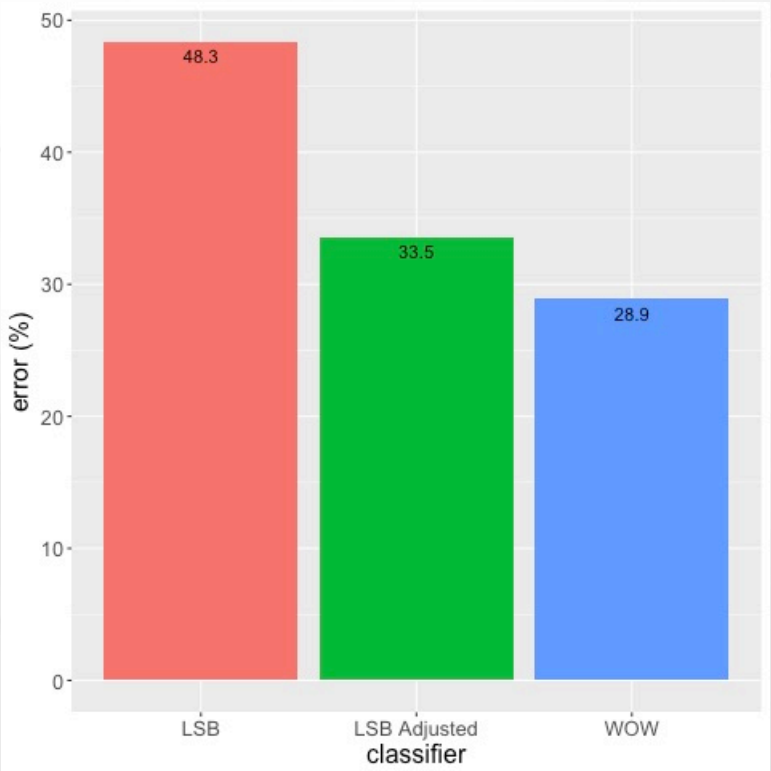
# Dataset 1: BOSSbase - 20% Embedding Rate

Average detection error on BOSSbase WOW data




- Testing on WOW 20% embedding rate
  - LSB Adjusted classifier uses adjusted threshold
  - WOW classifier uses standard threshold
  - Training set is 5,000 randomly selected cover-stego pairs and results averaged over 5 repetitions
- LSB adjusted classifier similar results to the “best-case” classifier



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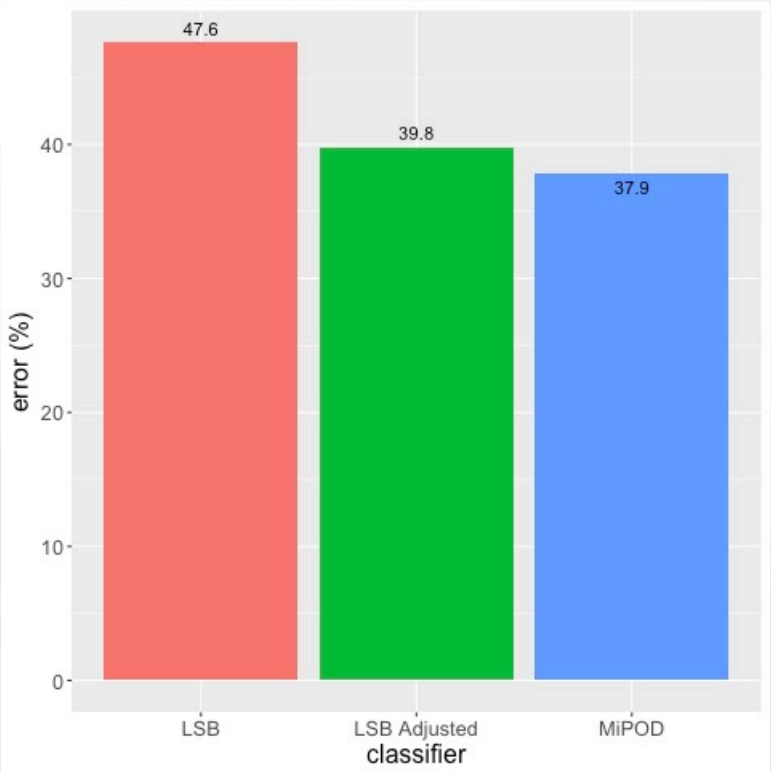
# Dataset 1: BOSSbase - 10% Embedding Rate

Average detection error on BOSSbase MiPOD data




- Testing on MiPOD 10% embedding rate
  - LSB Adjusted classifier uses adjusted threshold
  - MiPOD classifier uses standard threshold
  - Training set is 5,000 randomly selected cover-stego pairs and results averaged over 5 repetitions
- LSB adjusted classifier similar results to the “best-case” classifier



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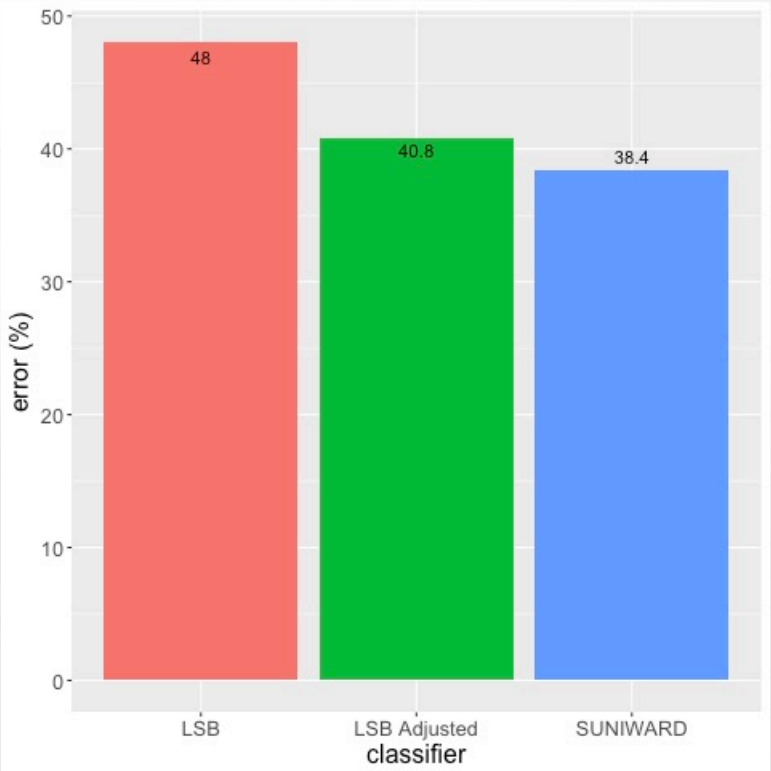
# Dataset 1: BOSSbase - 10% Embedding Rate

Average detection error on BOSSbase S-UNIWARD data




- Testing on S-UNIWARD 10% embedding rate
  - LSB Adjusted classifier uses adjusted threshold
  - S-UNIWARD classifier uses standard threshold
- LSB adjusted classifier within 2.5% of "best-case" classifier



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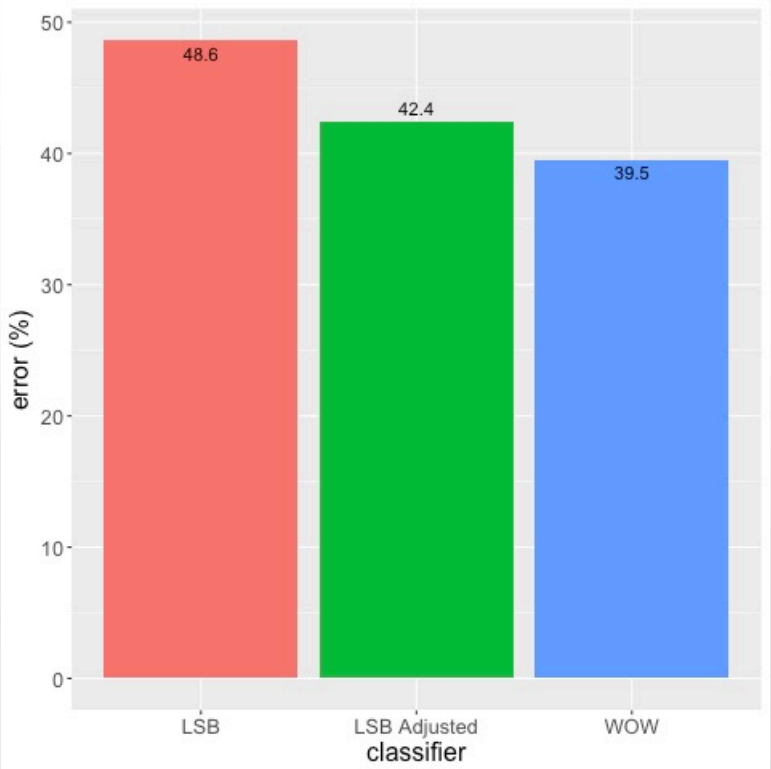
# Dataset 1: BOSSbase - 10% Embedding Rate

Average detection error on BOSSbase WOW data




- Testing on WOW 10% embedding rate
  - LSB Adjusted classifier uses adjusted threshold
  - WOW classifier uses standard threshold
- LSB adjusted classifier within 3% of “best-case” classifier



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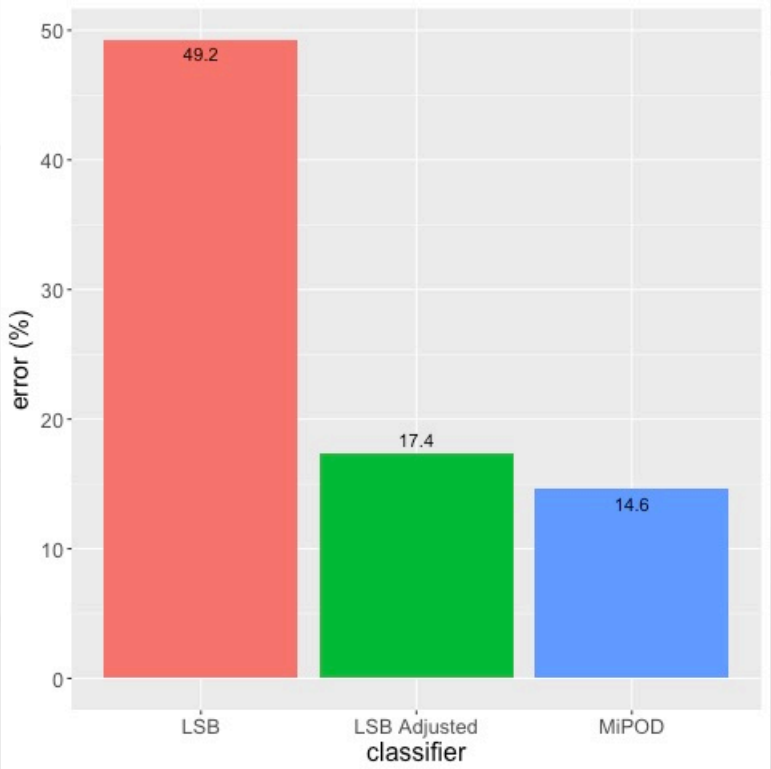
# Dataset 2: StegoAppDB - 10% Embedding Rate

Average detection error on StegoAppDB MiPOD data




- Testing on MiPOD 10% embedding rate
  - LSB Adjusted classifier uses adjusted threshold
  - MiPOD classifier uses standard threshold
  - Training set is 5,000 randomly selected cover-stego pairs and results averaged over 5 repetitions
- LSB adjusted classifier similar results to the “best-case” classifier



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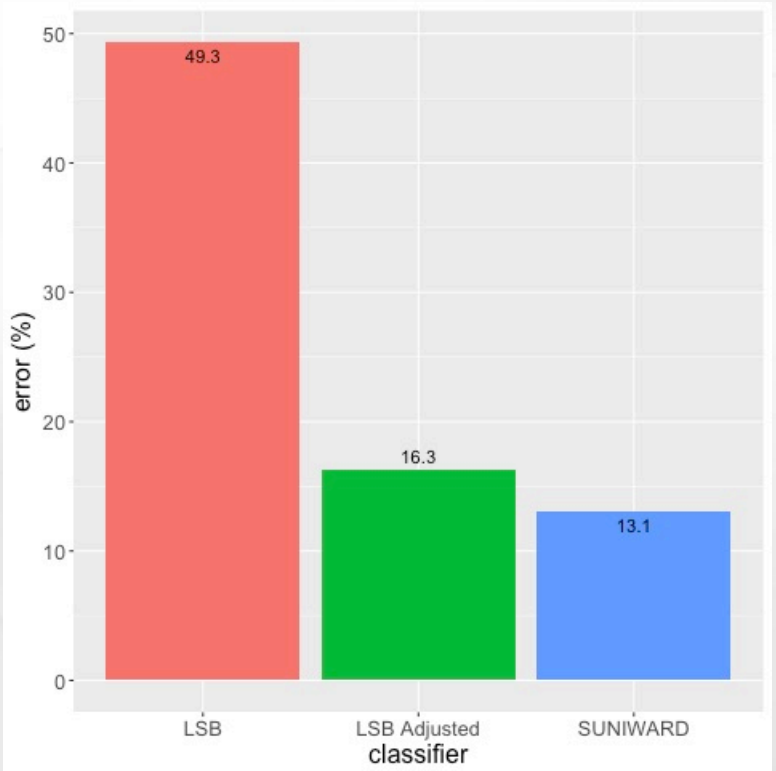
# Dataset 2: StegoAppDB - 10% Embedding Rate

Average detection error on StegoAppDB S-UNIWARD data




- Testing on S-UNIWARD 10% embedding rate
  - LSB Adjusted classifier uses adjusted threshold
  - S-UNIWARD classifier uses standard threshold
  - Training set is 5,000 randomly selected cover-stego pairs and results averaged over 5 repetitions
- LSB adjusted classifier similar results to the “best-case” classifier



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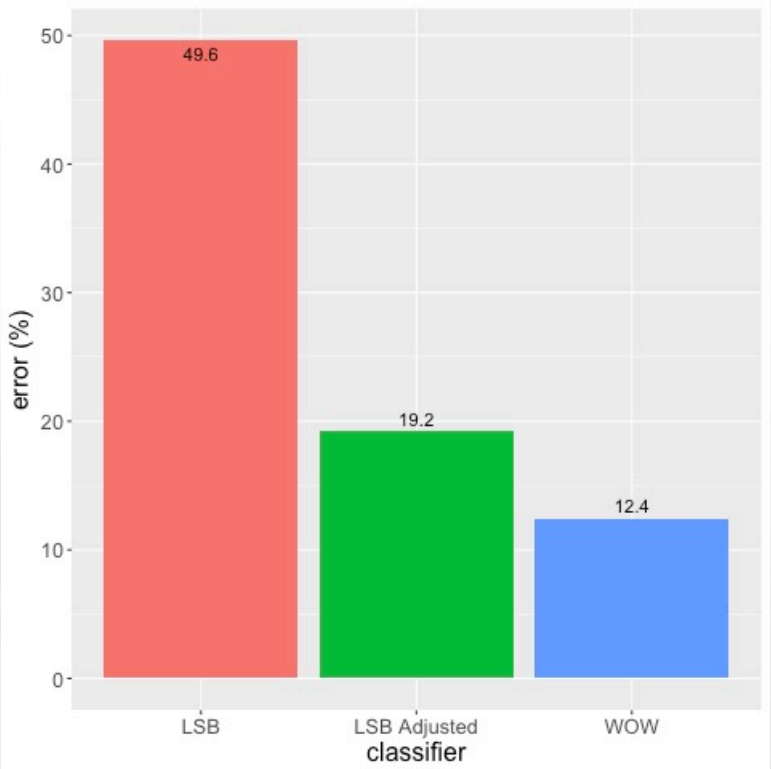
# Dataset 2: StegoAppDB - 10% Embedding Rate

Average detection error on StegoAppDB WOW data




- Testing on WOW 10% embedding rate
  - LSB Adjusted classifier uses adjusted threshold
  - WOW classifier uses standard threshold
  - Training set is 5,000 randomly selected cover-stego pairs and results averaged over 5 repetitions
- LSB adjusted classifier similar results to the “best-case” classifier



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# Conclusions and Future Work

- Conclusions
  - A classifier trained solely on covers and LSB matching can achieve detection error rates close to the "best-case" classifiers when testing on MiPOD, S-UNIWARD, and WOW
- Expand experiments to include more embedding algorithms
- Refine the process of selecting the tuning parameter $\lambda$

# StegoAppDB: Forensic Image Database

- https://data.csafe.iastate.edu/StegoDatabase/

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